NRL Report 5437
Erratum

# STEEL CORROSION MECHANISMS UNDER CONDITIONS PERTINENT TO STEAM POWER GENERATION

by

M. C. Bloom and Mary Boehm Strauss

Table C2, page 47. The Cl⁻ content of α FeOOH should read 0.01.

U. S. Naval Research Laboratory
Washington, D. C.

NRL Report 4911

# PROJECT CLINKER REPORT No. 5
## AN AMPLIDYNE POWER AMPLIFIER FOR USE WITH CHEMICAL PAPER RECORDERS

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April 4, 1957



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Washington, D.C.

## ABSTRACT

A novel, lightweight power amplifier has been developed for use with the NRL electrochemical recording paper and multifingered stylus. It consists of an amplidyne excited by a field control amplifier and negative feedback loop. When employed with the proper external limiting resistor, it is capable of providing acceptable current linearity over most of the dynamic range of the paper and will accommodate a variety of stylus widths. The frequency response is flat below 40 cps.


## PROBLEM STATUS

This is an interim report; work on the project is continuing.

## AUTHORIZATION

NRL Problem N03-01
Projects NR 562-000, NR 562-001,
and NL 430-014


Manuscript submitted February 14, 1957

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## INTRODUCTION

Electrochemical recording is being used extensively in connection with the airborne oceanographic studies under Project Clinker. For this purpose, it has been concluded that the best electrochemical paper is that developed by the Chemistry Division at NRL.[1] In addition, it has been determined that best stylus design is the multifingered array worked out by the Sound Division at NRL.[2] However, the type of data which is being recorded for Project Clinker requires a "printed" trace which varies from about 1/64 inch wide to almost 1/2 inch wide depending upon the type of measurement being made. During the recording operation, the stylus speed is usually about 3 inches per second but may go as high as 20 inches per second. The frequency range of the recorded signals is from about 0.1 cps to 40 cps. The full dynamic range of the recorder paper is required from the faintest mark at threshold to the darkest trace at saturation. At a stylus speed of 3 inches per second, a dc signal, when printed with a multifingered stylus 1/64 inch wide, must have a current swing from 60 microamperes to 40 milliamperes in order to realize the full dynamic range of the paper. The corresponding swing in the electrical resistance of the paper is from approximately $10^4$ ohms to 250 ohms. When a stylus 1/8 inch wide is employed, these quantities alter proportionately. The current swing becomes approximately 500 microamperes to 300 milliamperes; the resistance swing becomes, approximately 1500 ohms to 30 ohms.

Thus, it is apparent that the power amplifier, which supplies the marking current, must be capable of handling large current swings through a radically changing load. For this purpose, an amplidyne, which is excited by an electronic amplifier and controlled by negative feedback, has been found satisfactory.

## CHARACTERISTICS

The amplidynes are available in two frame sizes with output ratings of 150 and 530 watts, respectively. The 150-watt size (G.E. type 5AM21JJ7) has a 27-volt, dc, input with a 60-volt, 2.5 ampere output at 4000 rpm. The 530-watt size (G.E. type 5AM21JJ10) has a 24-volt, dc, input with a 60-volt, 8.8 ampere output at 7500 rpm. An intermediate size of 310 watts (type 5AM21JJ4A) has been produced in limited quantity but is not now available. This size has a 24-volt, dc, input and a 60-volt, 5.2 ampere output at 7500 rpm. Those used at NRL were obtained by having the General Electric Company rewind the 150-watt size. All types have a 3000-ohm resistance, center-tapped, control winding.

By themselves the amplidynes did not have the proper characteristics for the chemical paper recorder application. First, the frequency response was

[1] Kohn, E. J., Venezky, D. L., Rice, R. G., Ross, F. J., and Asbury, G. F., "The Development of the NRL Electrochemical Recorder Paper," NRL Report 4685, March 1956

[2] Neubauer, W. G., "A Multifingered Stylus for Use with a Current Sensitive Chemical Recording Paper," NRL Memorandum Report 398, November 1954

inadequate, a situation which was rectified with a negative feedback loop (Fig. 1). Secondly, because of the wide swing in paper resistance, the amplidyne had to be loaded down permanently with a 100-ohm shunt resistance placed across its output to secure proportionate control. And thirdly, because the chemical recording paper is current sensitive, a series resistor had to be placed between the amplidyne and recorder in order to make the amplidyne a current amplifier rather than a voltage amplifier. For the current swings desired, a 1000-ohm series resistor was found to be adequate for use with a stylus 1/64 inch wide. The size of this resistor was made proportionately less as the width of the stylus was increased. Thus, a 120-ohm series resistor was employed with a stylus 1/8 inch wide and so on.

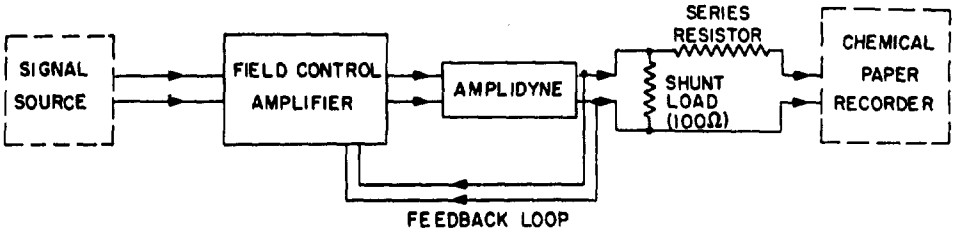


Fig. 1 - Block diagram of amplidyne power amplifier for use with NRL electrochemical recording paper and multifingered stylus

The details of the circuitry are shown in Fig. 2. A 6J5 is employed as a phase splitter for a 6SN7 which drives push-pull 6L6's. The 6L6's excite the control field of the amplidyne. Negative feedback from the output of the amplidyne is inserted into the grid circuit of the 6L6's by means of a resistor network which serves both as an attenuator and isolator. Prime power is taken from a 27.5-volt, dc, aircraft bus. Figure 3 shows the field control amplifier connected to a 150-watt amplidyne.

The frequency characteristic obtained with the 150-watt amplidyne is shown in Fig. 4. It exhibits a typical high frequency peaking due to the negative feedback and a low frequency fall-off due to the coupling capacitors between the first two stages in the field control amplifier. The size of these capacitors can be varied at will.

Because of the relatively large amount of power consumed at high signal levels by the external series resistor, the amplidyne must provide considerably more output power than that required by the chemical recording paper alone. For example, in the case of the 1/8-inch stylus moving at 3 inches per second, a 120-ohm series resistor is required to insure acceptable current linearity. However, the resistance of the paper is only 35 ohms at the maximum desired signal level of 300 milliamperes. Hence, more than 75 percent of the available power is dissipated in the series resistor under these conditions. The maximum voltage output required from the amplidyne is, therefore, approximately 50 volts peak. In this particular application of the amplidyne with an external series resistor, the maximum required voltage output is essentially the same for all stylus widths because the maximum required current is proportional to the stylus width, but the paper resistance and external resistance are inversly proportional to the width. It is apparent from Fig. 5 that the amplidyne is capable of producing a maximum of 36 volts rms or 50 volts peak without noticeable distortion. This curve was obtained with an external load of 100 ohms in parallel with the fixed internal shunt of 100 ohms. However, the output of the 150-watt amplidyne is quite independent of external loading provided that the total external load is

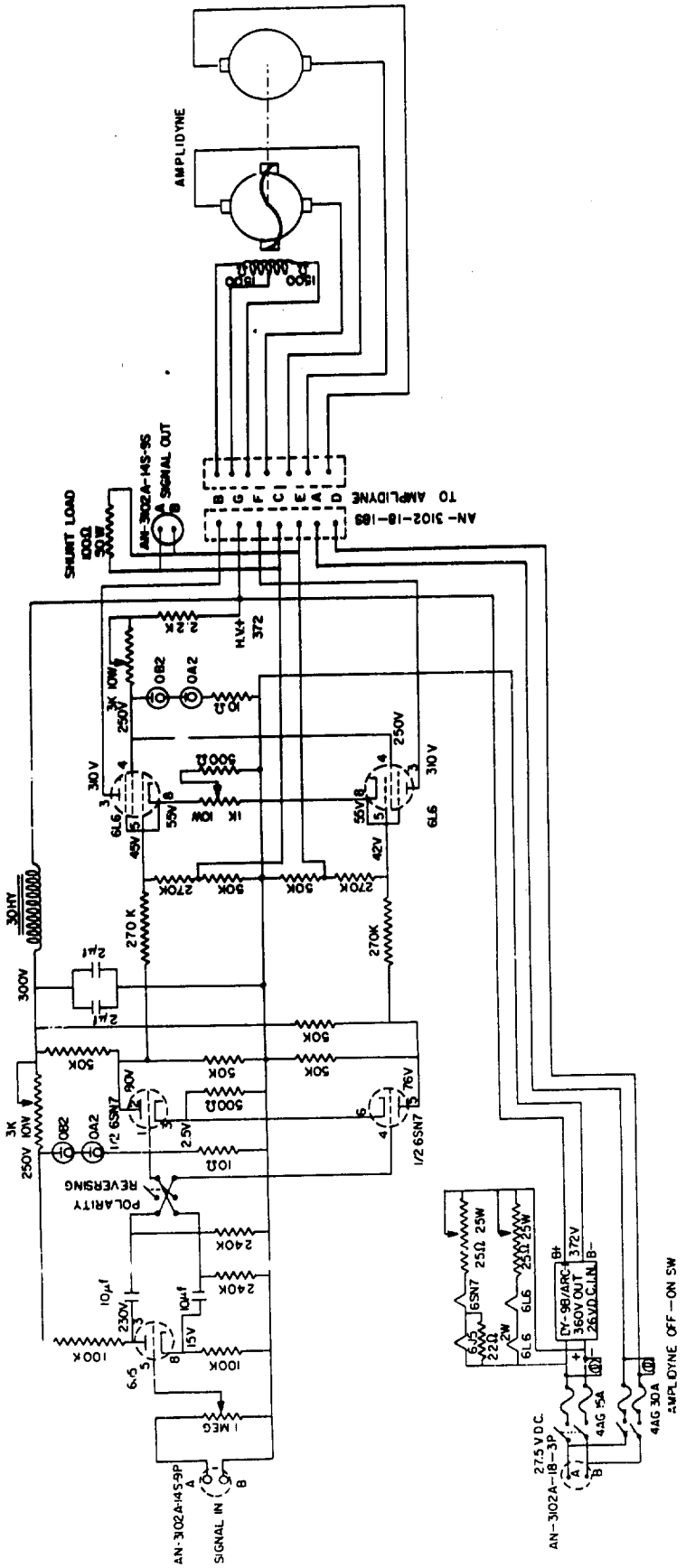


Fig. 2 - Circuit diagram of amplidyne power amplifier

Fig. 3 - Field control amplifier connected to a 150-watt amplidyne

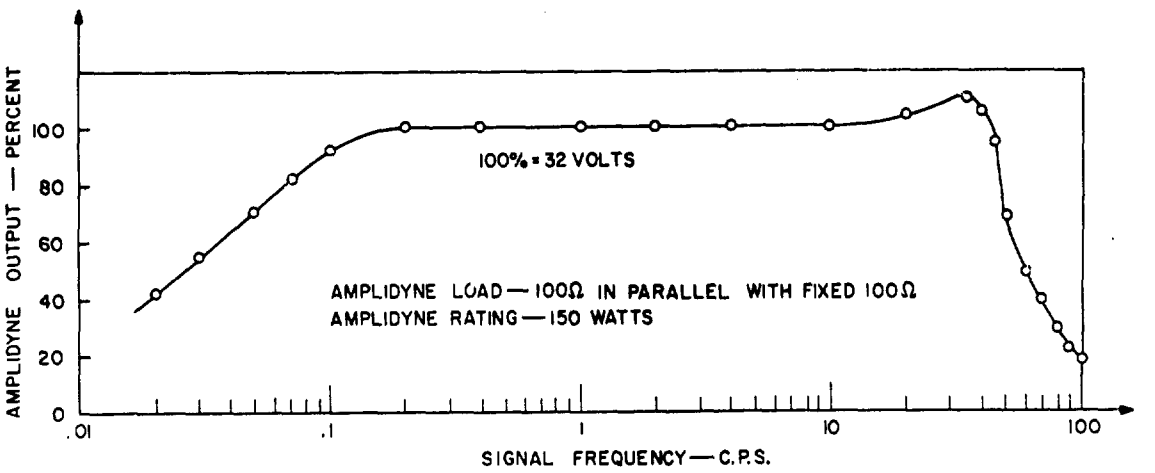


Fig. 4 - Frequency characteristic of amplidyne power amplifier

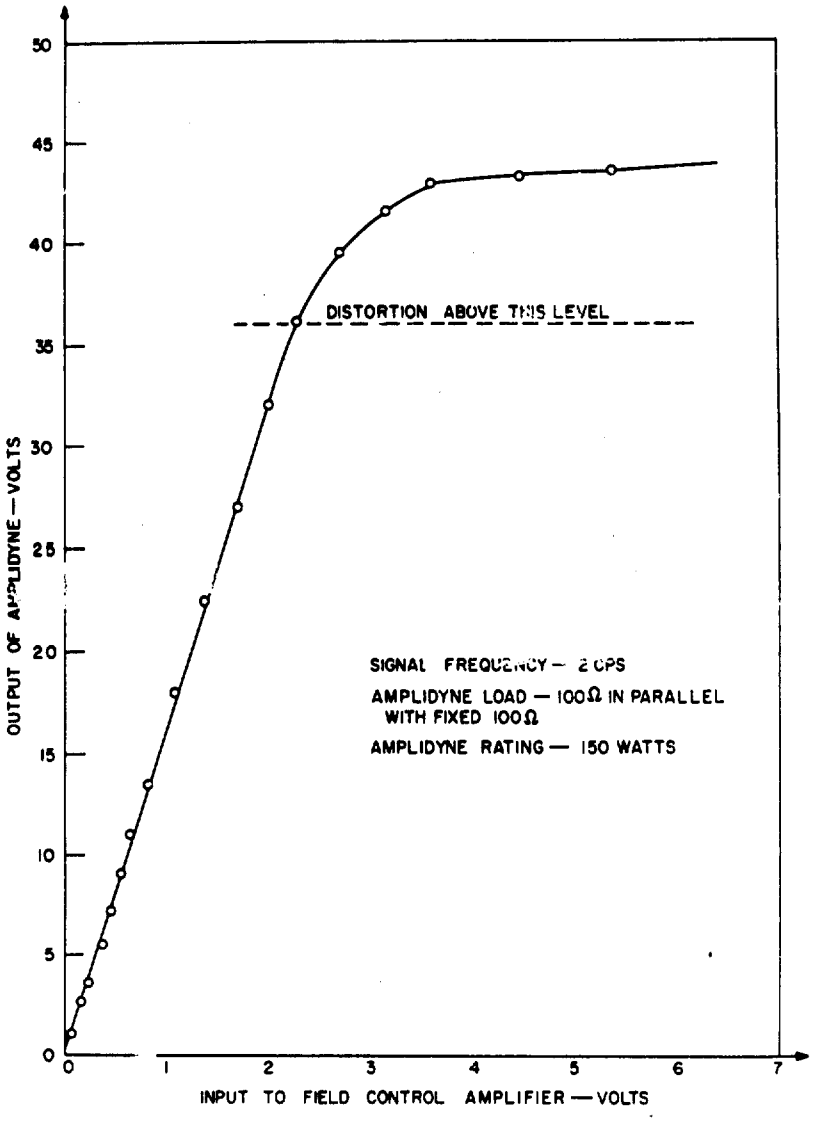


Fig. 5 - Linear characteristic of amplidyne power amplifier

not less than 30 ohms. This characteristic combined with the fact that the maximum required output voltage is the same for all stylus widths, when the correct series resistor is employed, makes the amplidyne amplifier well suited for use with a wide variety of stylii.

A 150-watt amplidyne and its associated field control amplifier have been employed successfully on Project Clinker for five years.

## CONCLUSION

An amplidyne, when properly excited by a field control amplifier and negative feedback loop, is a good, lightweight, airborne, power amplifier for use in recording signals below 40 cps on NRL electrochemical recording paper. With slightly different circuitry, it is also suitable for use with other chemical recording papers.

## ACKNOWLEDGMENT

This equipment was constructed originally by Mr. Leroy Guy and was improved at a later date by Mr. Horace Heitman, both of the Applied Optics Branch, Optics Division, NRL.

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